Short term scientific mission within COST Action MP1304: report

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PURPOSE

The main purpose of my short term scientific mission (STMS) at the Institute of Space Sciences (CSIC – IEEC) in Barcelona during the week 8-12th June 2015 was to measure the braking index of pulsars using all available radio, X-ray and gamma-rays observations, starting from the brightest and best monitored ones.

Pulsar braking index *n* might be considered as a trace of the magnetic field evolution of a pulsar. Assuming the spin-down is given only by the electromagnetic torque exerted by the dipolar magnetic field in vacuum, and that the field is constant in time, we would expect all pulsar having *n*=3. However, most of the measured index are smaller than 3 and up to now only about 12 precise measurements are available, despite the about 2300 pulsars known to date. The small number of measured *n* is reflecting the difficulty of having a reliable timing solution and second derivative of the spin period, which is polluted by the pulsar timing noise. It was shown that the majority of the pulsar had significant irregularities in their rotation rate, despite being considered stable clocks for decades. The differences between the observed and predicted times, known as the pulsar ¨timing residuals", in some cases were as large as many seconds, and often quasi-periodic, at variance with the belief of timing noise being a random noise. Lyne et al. (2011) have shown that the long-term quasi-periodic changes in the spin-down rates of many pulsars were mostly due to sharp changes in pulse profile. Modeling the pulse profile changes in time can then remove drastically the timing noise in the pulsar timing residuals, allowing a more robust measure of the second derivative of the pulsar, and the braking indexes.

DESCRIPTION OF THE WORK AND THE MAIN RESULTS OBTAINED

During my STSM in Barcelona, I worked mainly on the X-ray data analysis of the X-ray Dim Isolated Neutron Stars, XDINS. These are close-by and middle-age sources with a distance less than 500 pc, discovered by ROSAT. They are slow rotators, with period between 3 and 11 s, and highly magnetized, with inferred dipolar magnetic field strength of the order of 10^13 G at the surface of the star. Up to now there are seven confirmed XDINS, which appear to be thermally emitting with no emission outside of the X-ray soft band, except for optical/UV counterpart.

Inspired by the discovery of a phase-dependent absorption feature in the magnetar SGR 0418+5729 (Tiengo et al., 2013, Nature), we started to look for the presence of similar features in X-ray spectra of the XDINS. Thanks to this systematic investigation, we clearly found a phase-dependent feature in the spectrum of RX J0720.4-3125 during the longest available *XMM-Newton* observation. We performed a detailed phase-resolved analysis for all the available *XMM-Newton* observations, pointing out that the feature appears to be

relatively stable over the timespan covered by the observations, about 12 years. This feature is probably due to proton cyclotron resonant scattering in a magnetic loop near the surface and provides the first compelling evidence for the existence of non-purely-dipolar magnetic field configurations near the surface of these neutron stars.

During the STSM, I focused my work on another source among the XDINS, RX J1308.6+2127 (RBS 1223). Following the same procedure adopted for RX J0720.4-3125, I re-analyzed all the available *XMM-Newton* observations. We have constructed a timing solution for this source using the knowledge on timing analysis at the ICE-CSIC institute. In most of the phase-energy images built for each observation, a feature is evident only in a phase interval, giving a hint for the presence of a spectral feature in the corresponding spectrum. I´m still performing a detailed phase-resolved analysis in order to better investigate and constrain the presence of this absorption line.

FORESEEN PUBLICATIONS/ARTICLES RESULTING FROM THE STMS

During the stay at CSIC-IEEC, we re-submitted the article with the title ¨Discovery of a strongly phase-variable spectral feature in the isolated neutron star RX J0720.4-3125¨ (arXiv:1506.04206) to The Astrophysical Journal Letters and the article was accepted for publication. Moreover, I prepared a talk concerning this article for the Annual NewCompstar Conference 2015, which took place in Budapest on 15-19th June 2015.

The timing and spectral analysis we did on RX J1308.6+2127 will be included in a future work, where we will also present an overview about the presence of phase-dependent features detected so far in the X-ray spectra of the XDINSs.

FUTURE COLLABORATION WITH THE HOST INSTITUTION

I´m going to continue a collaboration with the Institute of Space Sciences (CSIC – IEEC) in Barcelona in order to broaden my knowledge on timing analysis, timing techniques and current gamma-ray, X-ray and radio timing tools thanks to Jian Li and Alessandro Papitto, post-docs working in the MAP Research group (http://www.ice.csic.es/research/map/MAP.html).